Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 86 (2016) 313 – 316

Procedia Computer Science

2016 International Electrical Engineering Congress, iEECON2016, 2-4 March 2016, Chiang Mai, Thailand

Non-thermal dielectric barrier discharge generator

Khanit Matra*, Sommavan Wongkuan

Department of electrical engineering, Engineering faculty, Srinakharinwirot University, 63 M.7 Rangsit-Nakhonnayok road, Ongkharak, Nakhonnayok 26120, Thailand

Abstract

The purpose of this paper is to study and design a non-thermal dielectric barrier discharge generator generated by a dc power supply, by designing two different geometries of the electrode. One is a planar electrode model, and the other is a plasma jet model. The design is to study and compare the two types of plasma models with analyzing discharge voltage and current waveforms. From the experimental result, arc discharge usually occurred at the corner of planar electrode model while the plasma jet model could be operated in the stable glow discharge mode. The plasma characteristics were controlled by modifying the value of the electrode gap distance, source voltage, and gas flow rate. The discharge waveforms were dependent on the electrode gap distance and the voltage of the power supply. At a stable supply voltage, the size and intensity of plasma increased with the increasing of the gas flow rate.

Peer-review under responsibility of the Organizing Committee of iEECON2016

Keywords: non-thermal, plasma generator, dielectric barrier discharge ;

1. Introduction

Nowadays, non-thermal dielectric barrier discharge (DBD) or silent plasma is very useful for developing future technology. This is owing to the special properties of DBD; for example, it is able to be generated in a wide range of pressures from near vacuum to atmospheric pressure, scalable plasma size, and act as reactor for a chemical reaction. Therefore, DBD has already been applied in many fields such as the electronic industry, medical treatment, and the light source for excimer ultraviolet lamps. Moreover, since it possesses essential advantages in high safety and causes no genetic changes, DBD is thus appropriate for applying to agriculture industry in Thailand[1,2,3].

* Corresponding author. Tel.: +662-649-5000; fax: +663-732-2602.
E-mail address: khanit@g.swu.ac.th

Peer-review under responsibility of the Organizing Committee of iEECON2016
doi:10.1016/j.procs.2016.05.085

In this preliminary research, a dc non-thermal plasma source has been designed and developed by using two simple dielectric barrier discharge models. Which are planar electrode plasma model and plasma jet model (coaxial electrode)[2]. The experiments were conducted in a room environment. To understand the electrical characteristic of dc dielectric barrier discharge, the controlled parameters such as electrode gap distance, gas flow rate, and source voltage were studied[1,3,4,5].

2. Design of the DBD models and experimental set up

The first model of DBD plasma is a planar electrode plasma model illustrated in Fig. 1(a). Two 45×55 mm copper plates with 3 mm in thickness were placed in parallel and separated by air and acrylic plate with 2 mm in thickness. The gap between the acrylic plate and the lower copper cathode was 2 mm. Both copper plates were enclosed by acrylic plates, with 70×70 mm^2 and 3 mm in thickness. Three holes were drilled on the lower acrylic plate for gas inlet and gas outlet.

Another model is plasma jet illustrated in Fig. 1(b). The copper anode rod with 1 mm in diameter and 150 mm. in length were inserted into the center of glass tube, which has 6 mm in diameter and 200 mm in length. 1 mm in diameter copper ring-shaped cathode was worn on the outside of glass tube. Argon gas from the Argon gas cylinder was fed to the model through the plastic tube and hooked by the plastic cork at the tip of glass tube.

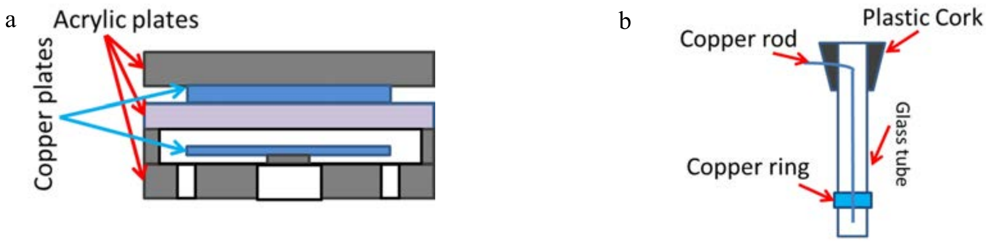

Fig. 1. (a) planar electrode plasma model; (b) plasma jet model.

The circuit diagram of the planar electrode plasma model and the plasma jet model is the same and shown in Fig. 2(a). To switch the plasma model, the model could be changed by placing the other model in the red dash frame area. Argon gas flow rate was controlled by a pressure gauge. A dc high voltage power supply with the maximum voltage of 30 kV was used to ignite plasma. A 500 kilo ohm ballast resister was connected in series with the dc power source to the anode. The characteristic of the discharge voltage was monitored by an oscilloscope with a high voltage probe (Pintek HVP-28HF). The discharge current waveform was calculated across the 50 ohm shunt resistor connected in series from the cathode to ground.

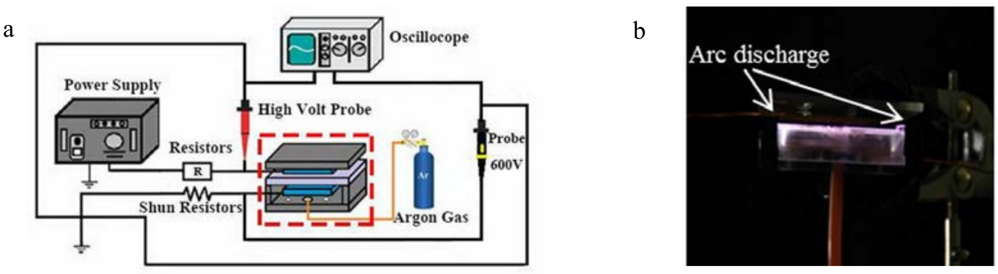

Fig. 2. (a) schematic diagram of DBD plasma set up; (b) arc discharge often occurred at the corner of electrodes.

3. Experimental results and discussion

After supplying the model with a sufficiently high source voltage and with the flowing of Argon gas, DBD plasma could be ignited. From the experimental results, arc discharge usually occurred at the corner of planar electrode model. This was due to the high electric field stress at the corners of the electrodes resulting in the arc discharge as depicted in Fig. 2(b). In contrast, the DBD plasma jet model could be easily operated with stable glow discharge; therefore, only the plasma jet model was discussed for the rest of this paper.

3.1. Effect of the gas flow rate on discharge characteristics

The plasma jet characteristics after adjusting the value of the gas flow rate at 5, 10, and 15 liters per minute, keeping the 15 mm gap distance from the copper ring-shaped to the end of the tube and supplying DC source voltage at 8.5 kV are illustrated in Fig. 3(a). The visible plasma jet length was increased from 24 to 27 and 30 mm after an increase of the gas flow rate. Fig. 3(b) shows the result of discharge voltage and current waveforms at the same experimental condition. The breakdown voltages for every gas flow rate were approximately the same as 8.45 kV, while the discharge current was 0.96 – 5.2 μA, 1.84 – 5.68 μA, and 1.12 – 4.96 μA for the gas flow rate at 5, 10, and 15 LPM, respectively. From these experimental results, increasing the gas flow rate does not influence the breakdown voltage and current much, but it has a significant effect on the length of plasma. When the gas flow rate was increased, the length of plasma jet increased as well. It should be mentioned here that the dropping of discharge voltage together with an abruptly increasing pulse discharge current are due to an accumulation of the big avalanche free charges travelling across the gap which is the drawback of dc DBD model. However, it could be solved by designing the proper ballast resistor to limit the pulse current.

a

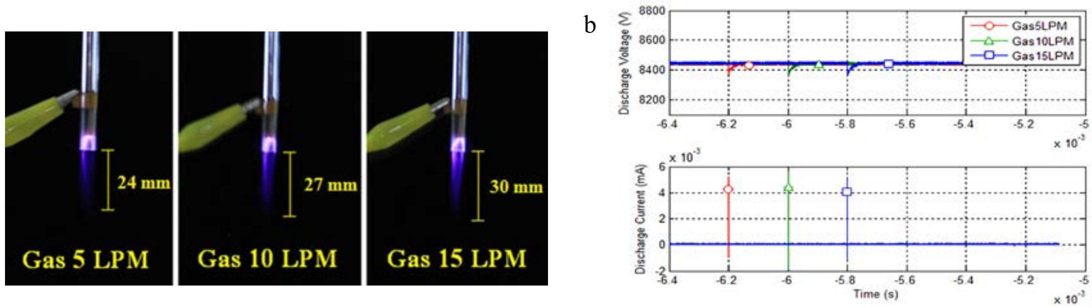

Fig. 3. (a) the length of plasma jet at various gas flow rates at the source voltage of 8.5 kV; (b) discharge voltage and current waveforms for gap distance of 15 mm, source voltage of 8.5 kV at the various gas flow rates.

3.2. Effect of gap distance on discharge characteristics

To study the effect of gap distance on the discharge characteristics, gap distances between the copper ring-shaped cathode and the end of the glass tube were adjusted to 10, 15, 20, 25, and 30 mm. At the same Argon gas flow rate of 5 LPM, and the maximum discharge voltages which could generate stable glow discharge before transition to arc discharge were 8, 8.5, 9.6, 11.5, and 15.7 kV for the gap length of 10 to 30 mm, respectively as illustrated in Fig. 4(a). At these experimental conditions, the maximum visible plasma jet lengths were 22, 26, 28, 28, and 29 mm, respectively. The plasma color was also intensified when the plasma was driven by high source voltage due to the energetic photon energy from the emission spectra of the atoms in plasma. Fig. 4(b) presents the discharge waveforms of the experimental condition of 5 LPM gas flow rate, 15 mm gap distance at the source voltage of 6.2, 8 and 9 kV. It could be noticed that the discharge voltages increased with the increase of source voltage. From these results, it could be implied that the plasma was operating in the abnormal glow region[6,7].

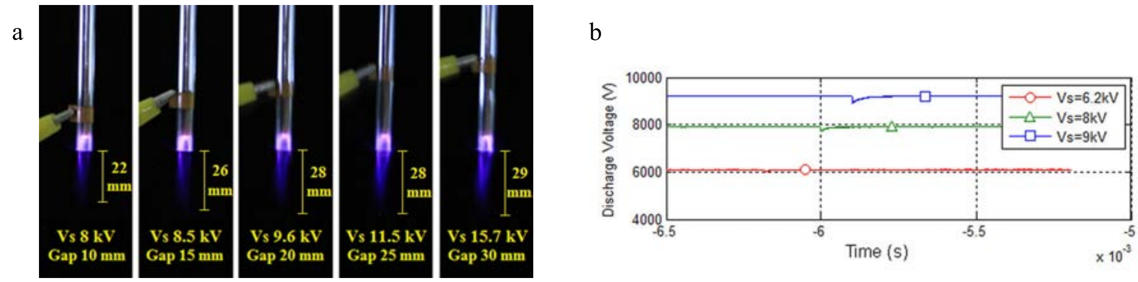

Fig. 4. (a) the plasma jet images for the gas flow rate of 5 LPM at various conditions; (b) discharge voltage and current waveforms for the gas flow rate of 5 LPM, the gap distance of 10 mm and at various source voltages.

4. Summary

The preliminary research on dc atmospheric non-thermal DBD plasma was proposed. Two simple DBD models were studied. Arc discharge frequently occurred at the corners of the planar electrodes of the planar model while the other plasma model, plasma jet, could be easily controlled in the stable glow discharge. From the experimental results, it could be confirmed that the increasing gas flow rate does not show much effect on the breakdown voltage, but does show effects on the length of plasma jet. Increasing the gap distance was resulting in the increasing of breakdown voltage.

Acknowledgements

This work was supported by Srinakharinwirot University. Moreover, the author would like to express thanks to all students belonging to the Atmospheric Plasma Engineering Laboratory (APEL).

References

1. Chirokov A, Gutsol A, Fridman A. Atmospheric pressure plasma of dielectric barrier discharges. *Pure and Applied Chemistry,* 2005; **77**:487-495.
2. Kogelschatz U, Eliasson B., 2000. “Fundamentals and applications of dielectric barrier discharges.” In HAKONE VII Int. Symp. On High Pressure Low Temperature Plasma Chemistry, Greifswald.
3. Morgan N. N. Atmospheric pressure dielectric barrier discharge chemical and biological applications. *International Journal of Physical Sciences*, 2009; **4**: 885-892.
4. Ren Y, Zhu X, Fan D, Ma P, Liang L., 2012. “Mutation induction by dbd plasma in phosphate-solubilizing.” In International Conference on Future Energy, Environment, and Materials, p. 211–216.
5. Hippler R. *Low temperature plasmas: Fundamentals*, technologies and techniques 2nd. Weinheim: Wiley-VCH; 2008.
6. Matra K, Furuta H, Hatta A, Current-voltage characteristics of dc discharge in micro gas jet injected into vacuum environment, *Journal of Physics: Conference Series*, 2013; **441:** 012021.
7. Bogaerts A, Neyts E, Gijbels R, Van der Mullen J. Gas discharge plasmas and their applications. *Spectrochimica Acta Part B: Atomic Spectroscopy,* 2002; **57**: 609-658.